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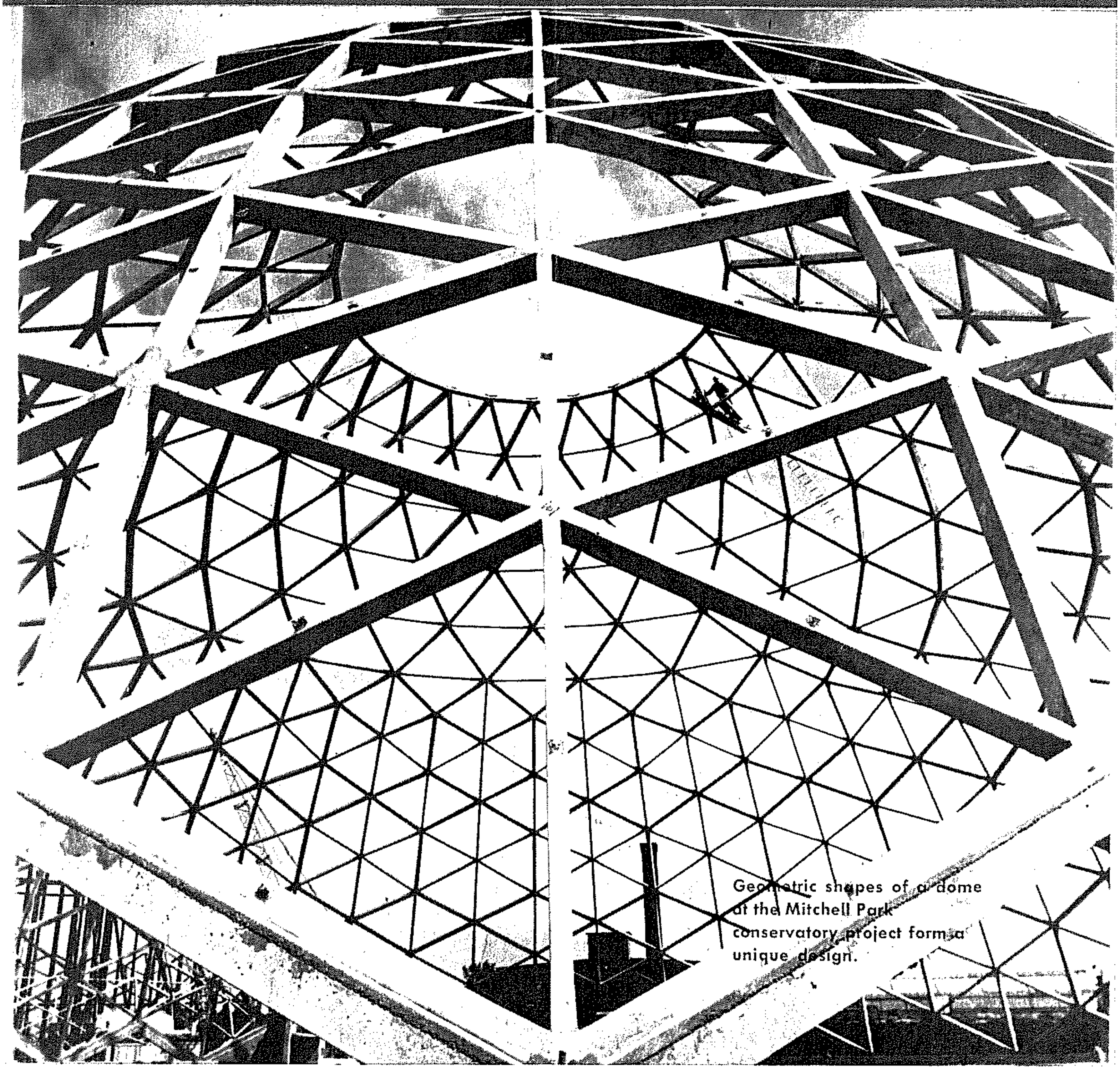
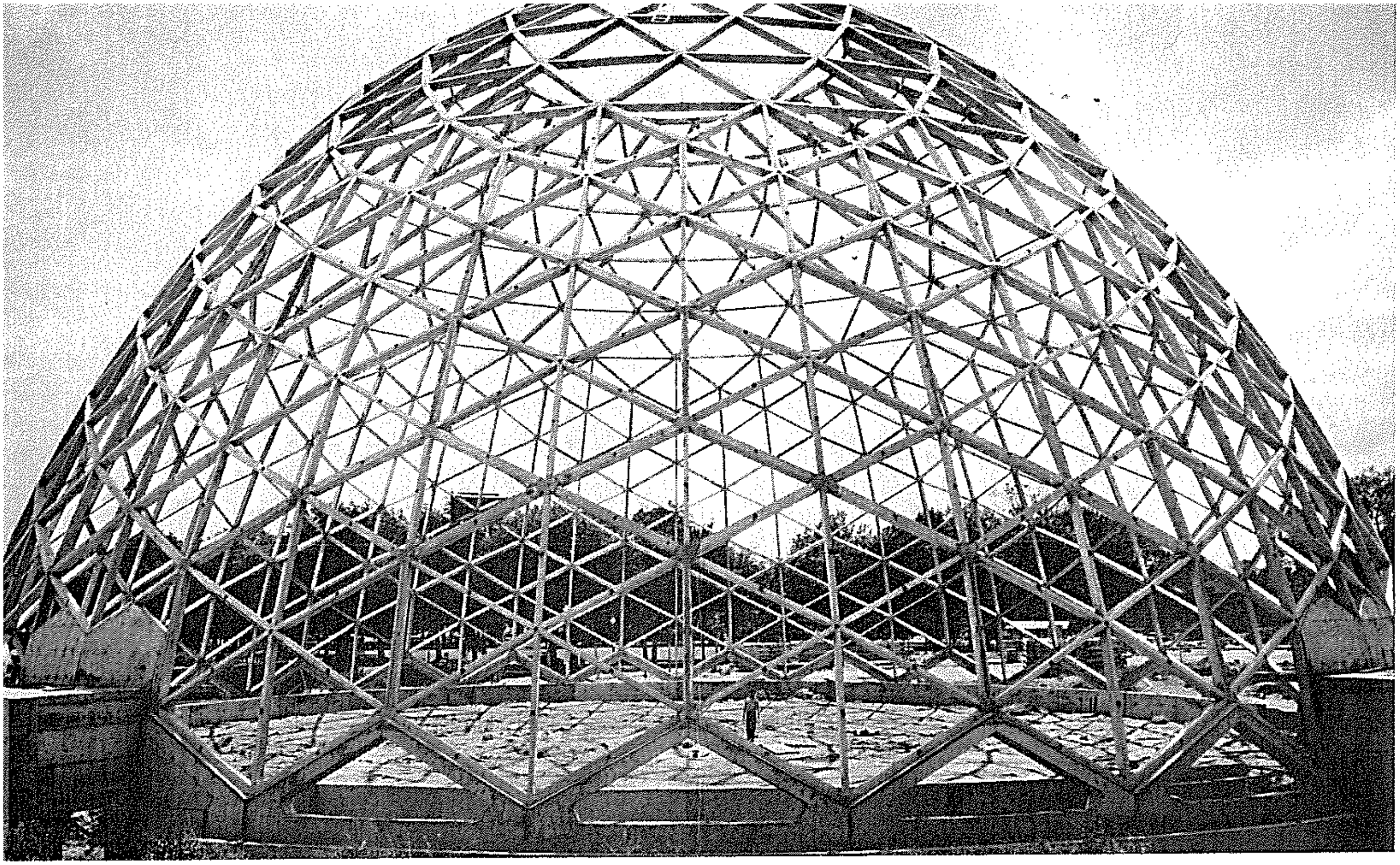


Geometric shapes of a dome at the Mitchell Park conservatory project form a unique design.



Three giant domes are being built at Mitchell Park Conservatory under the direction of Donald L. Grieb of Milwaukee. The domes, the first of their kind in the world, are 70 feet high and 140 feet in diameter.

World's First Space Frames Rise in Milwaukee

Rising on the horizon of Milwaukee's southwest side are two giant domes — part of the 3½ million dollar Mitchell Park conservatory project — which will exhibit plants from remote reaches of the world.

When completed about early 1964, the conservatory development will consist of three complex conoids, or domes, as they are more commonly called.

Made of precast concrete, covered with aluminum and glazed with glass, the domes will be unique in the world. Radically different from the standard gable type roof design for greenhouses, each dome will have a different climate.

The tropical dome, which will house plants like banana and rubber trees, will feature an undulating jungle path and a tropical waterfall. The arid dome will have an oasis amid desert plants. The temperate dome will be used to present seasonal shows of North American plants.

According to plan, the domes are being built to form a triangle, with the arid dome at the apex. The latter will be fronted by an administration office and a foyer leading to entrances to each dome.

The project is being built for the Milwaukee County Park commission under the direction of Milwaukee Architect Donald L. Grieb. The renowned firm of Ammann & Whitney, of New York and Milwaukee, was employed by Grieb to provide structural engineering studies and working drawings.

Foundation work for the first two domes was under contract to Stevens Construction Corp., Milwaukee. Contract for the base of the third dome was let to Reichl & Sons, Milwaukee.

The problems encountered in the design of the domes were immense.

The curve of the domes had to be at a certain degree to permit the proper amount of light ray penetration for good plant growth. Condensation drip and high humidity, discomforting aspects of most greenhouses, had to be eliminated in order to give the viewing public inviting atmospheric conditions.

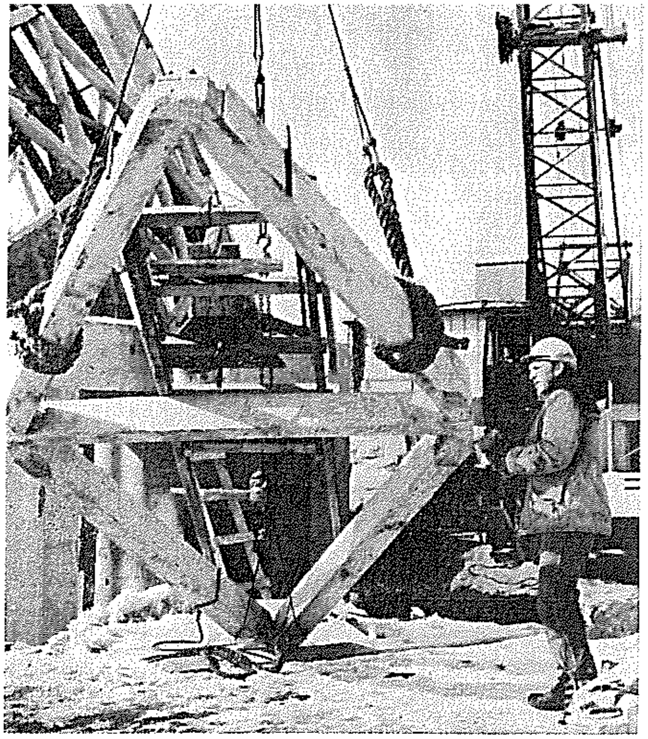
With these basic considerations, Grieb designed the world's first open space frame in the shape of a complex conoid — and then copyrighted the configuration.

Structural engineers at Ammann & Whitney were pleased with the challenge and chance to work with Grieb's new form.

"Almost at the outset," Robert Hopwood, manager and chief engineer for the Milwaukee office of Ammann & Whitney, declared, "we decided to use concrete on this structure as the most practical material to resist the attacks of moisture and insecticides from within the domes."

Having furnished the firm with a revolutionary design, Grieb requested that the domes' surfaces permit 75 per cent unobstructed light to enter.

"Ordinary smooth domes are not difficult to design," Hopwood continued. "We began the design as a smooth surfaced one, then switched to a patterned surface, much



This diamond-shaped unit is being lifted to the fourth tier of a dome.

A welder scales the side of a dome to weld gusset plates at corners of units.

the same as one would do in the design of a truss to replace a beam design. The principal stresses in a dome are compression along the meridians and either compression or tension along the horizontal circles.

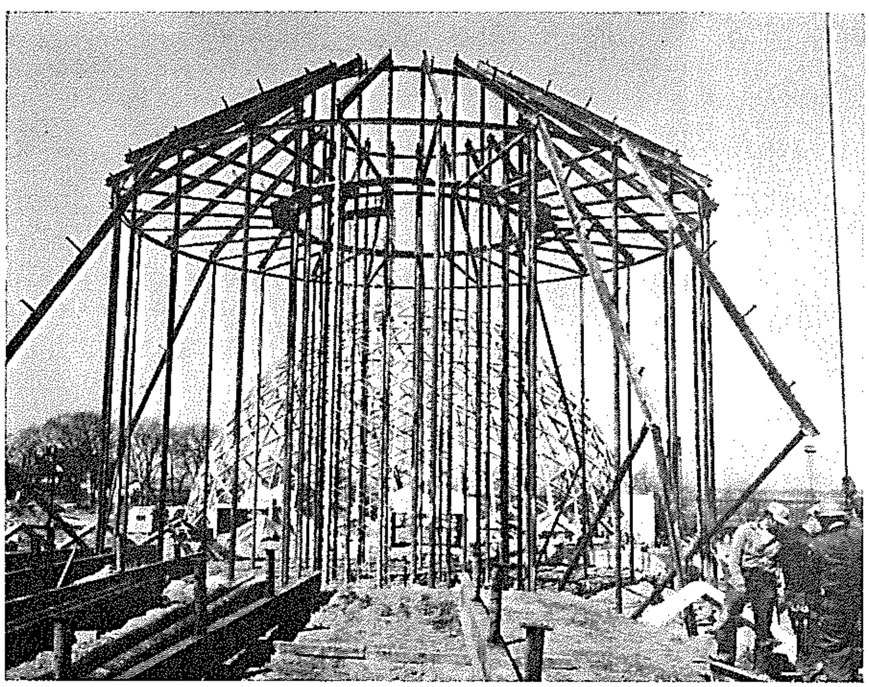
"The first step was to find what patterns of members were suitable to carry the resolved stresses and maintain stability in the structure. These patterns were discussed with the architect for his final choice in beginning his aesthetic treatment of the structure.

"Due to the large cost of the form work, it was decided to detail the domes for precast handling by selecting field joints to create the smallest number of members and at the same time provide the greatest re-use of forms."

Hopwood added, "The design strength of the concrete was limited to 5,000 psi and the plastic or ultimate theory was used in the final design."

With working drawings available, Hufschmidt Engineering Co., Menomonee Falls, submitted a bid for the construction and erection of the superstructure for the first two domes and was awarded the contract. (He subsequently was awarded a contract for the third dome.)

The architect's specifications were the end result type because of the complex nature of the castings and erection. Grieb's plans showed the four basic radii of a dome and one of the precast pieces making up one segment of the dome. The method of casting and erection, while subject to Grieb's approval, was left entirely to Hufschmidt Engineering.



President John Hufschmidt was faced with a myriad of problems. However, at the same time these problems allowed him and his engineers to use their ingenuity in the design of forms, casting pieces and method of temporary falsework supports.

The three domes, 70 feet high and 140 feet in diameter, are being built of six different sizes of precast units. The units have three basic shapes: The first three tiers of each dome are composed of hexagonal pieces — with six spokes radiating from a center point to the corners; the second two tiers are diamond shaped — with a cross strut; and the top tier of each dome consists of triangular units.

Each tier requires 25 units. As the tiers move upward, the precast units decrease in weight and size, however, 25 units are needed to complete each ring.

The saw-toothed shape foundations

Steel pipe columns and I-beams support the precast units during erection.

of each dome are built to fit the hexagonal units. These foundation walls rest on thick slabs. A moat, formed by the foundation wall and an inner wall of each dome, will be used for utilities.

The problems involved in making forms for the different sizes of precast units were complex. The two directional curve of the domes added to the complexity.

Forms for the units were made of concrete. Steel was considered but rejected for two chief reasons: The high cost of steel fabrication and the poor weatherability of steel as compared to concrete.

Construction of the concrete molds followed much the same procedure as that used in foundries.

Plaster of paris models were made for each of the three different shaped units that make up the domes. At the site, the model was fastened to a casting pallet. A wood perimeter form was then placed around the plaster model and reinforced concrete was poured over the model.

After the form had cured sufficiently, a crane turned over the huge chunk of concrete and the plaster was chipped out. Before units could be made, triangular concrete "loose pieces" had to be cast. These pieces are placed in the forms during casting but removed before a finished precast unit can be extracted from the form. The pieces allow for draft or draw of the units.

The reinforcing for a precast unit is made of two reinforcing bars wrapped with wire. The top bar of this cage extends from the corners of the concrete unit, where they are welded to gusset plates and then to adjoining units as they are erected.

By late August of 1959, the first casting took place. Realizing the small quantity of concrete required for each day's casting, Hufschmidt's engineers decided to make the concrete at the job site. Casting continued last week.

A one bag concrete mixer was set up close to the forms and the concrete deposited into the molds by wheelbarrows. Before the concrete was placed, however, the forms were painted with a bond-breaking agent.

After three days of curing, the loose pieces and movable wood inner sides were stripped from the forms. A crane lifted the units from the forms and placed them on a stock pile. All surfaces are hand rubbed. In the finished domes, they will be painted with two coats of special paint that will not support fungi growth.

To support the units during erection Hufschmidt decided to use a falsework made of 8 inch pipe columns with I-beams that roughly outlined the shape of a dome. This support system allows for a maximum amount of clear space for the daily checking of pieces as they are erected. Also, this system can be disassembled and removed from a dome easily. About 100 tons of steel were necessary for this support system.

To the I-beams are welded steel stools to meet the exact shape of the domes. Two bolts in a plate at the top of each stool allow for fine adjustment.

Erection of the units takes considerable care. A crane hoists each piece onto the falsework. As each precast unit is set in place, its position is checked by measuring its distance out from the center point of the dome and its height above the floor. The position of the unit is then adjusted by the bolts on the steel stools attached to the falsework.

Vertical distances are projected by use of a heavy plumb bob hanging from the unit and swinging free in a pail of oil. This is necessary to correct for excessive height and wind sway of the bob.

These coordinate points are extremely important, because any movement of the dome pieces in or out from the center would change the dome's diameter. If the diameter changed, the 25th piece in any ring would not fit. Welding and grouting follow.

Under a separate contract, yet to be let, the tops of the domes will be covered with aluminum. The rest of the surface will be glazed. Small conduits in the sashing will channel condensation from inside the domes to the ground.